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ABSTRACT

Researchers have noticed a gap between mathematics practice in school and mathematics practice in out-of-school situations. This study compares the out-of-school practice involving measurement of on-the-job carpet layers with the problem-solving strategies of ninth-grade students while engaged in measurement problems from the typical mathematics textbook. Data collection in the carpet-laying field work included participant observation, ethnographic interviewing, artifact examination, and researcher introspection. Data from the seventh- and eighth-grade textbooks were collected through content analysis of examples, exercises, and problems in the textbooks related to the concept of measurement. Data from the students included observation, informal interviewing, and researcher introspection. The carpet layers made use of four categories of mathematical concepts--measurement, computational algorithms, geometry, and ratio and proportion--and two categories of mathematical processes--measuring and problem solving. Analysis of the textbook problems indicated that students were involved in computational exercises whereas carpet layers were involved in measurement. Differences between students and carpet layers included a lack of deep understanding of the concept of area on the part of the students and more problem-solving skills and strategies on the part of the carpet layers. Contains 26 references. (MDH)

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Comparing In-School and Out-of-School Mathematics Practice

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This paper is based on the author's dissertation, *Mathematics Practice and Apprenticeship in Carpet Laying: Suggestions for Mathematics Education*, completed in 1992 at Indiana University-Bloomington under the direction of Frank K. Lester, Jr.

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Introduction

> Mathematical knowledge has commonly been portrayed as consisting of universal truths which exist independently of people and which are discovered by mathematicians through a process of formal reasoning. Mathematical reasoning, unlike any other cognitive activity, is believed to be a decontextualized activity, tied to a formal system which relies upon a specifically defined set of symbols. These ideas have led to a view of mathematics as divorced from ordinary human activity and devoid of social, cultural and political considerations. (Millroy, 1992, p. 1)

Prior to the last decade, conventional wisdom was that mathematics was culture-free knowledge. Now it is generally accepted that mathematics has a cultural history and that mathematics learning occurs during participation in cultural practices as well as in school. However, researchers that have examined mathematics practice in school and mathematics practice in out-of-school situations have noted the gap between these two (e.g., Brenner, 1985; Carraher, 1986; Carraher, Carraher & Schliemann, 1985; Ferreira, 1990).

Knowledge gained in out-of-school situations often develops out of activities that: (a) occur in a *familiar setting*, (b) are *dilemma driven*, (c) are *goal directed*, (d) use the learner's own *natural language*, and (e) often occur in an *apprenticeship* situation allowing for observation of the skill and thinking involved in expert performance (Lester, 1989). Knowledge acquired in school all too often grows out of a transmission paradigm of instruction and is largely devoid of meaning (lack of context, relevance, specific goal). Resnick (1989) has argued that schools place too much emphasis on the transmission of syntax (procedures) rather than on the teaching of semantics (meaning) and this "discourages children from bringing their intuitions to bear on school learning tasks" (p. 166).

Students need in-school mathematical experiences to build on and formalize their mathematical knowledge gained in out-of-school situations. An important part of a

mathematical experience in school is the guidance and structure that can be provided by a teacher to help students make connections among mathematical ideas. The gap between in-school knowledge and out-of-school knowledge results in a form of cultural discontinuity—a gulf between the culture of the school and the culture of the students' everyday lives. The problem of cultural discontinuity is well documented (Spindler, 1974). As Singleton (1974) noted, culture encompasses "patterns of meaning, reality, values, actions and decision-making that are shared by and within social collectivities" (p. 28). All these patterns are needed for the learning of mathematics (Bishop, 1985). When children are faced with learning mathematics apart from their everyday patterns, they have difficulty linking the in-school mathematics with their out-of-school mathematics. The end result is that the students memorize information in school without understanding how it fits with the realities of their lives.

Structure of the Study

This study was based on the assumptions that mathematical knowledge is a type of cultural knowledge and as such, the mathematics curriculum associated with formal school should engage students in mathematical practice where the knowledge is situated in the context of its use. It is my contention that the gap between in-school and out-of-school mathematics practice can only be narrowed after ways in which mathematics is meaningful in the context of everyday life have been determined. A number of researchers have examined mathematics practice in out-of-school situations. The majority of these studies examined the use of arithmetic and geometric concepts and processes.

To extend this research to an out-of-school situation involving measurement, I chose to examine the mathematics practice of a group of carpet layers to identify the mathematics concepts and processes used in this context. To connect this out-of-school mathematics practice with in-school mathematics, I then compared: (a) the concept of measurement and the process of measuring as presented in seventh- and eighth-grade

mathematics textbooks with the occurrence of these in the carpet laying context, and (b) the school-based knowledge of general mathematics students with the experience-based knowledge of carpet layers in solving carpet laying problems.

Various conceptual, theoretical, and methodological frameworks guided the conceptualization, design, and conduct of this study: a cultural framework, an epistemological framework, a cognitive framework, and a methodological framework.

Cultural framework

This study considered mathematics practice from an ethnomathematics approach, that is recognizing the influence that sociocultural factors have on the learning and teaching of mathematics (Scott, 1985). Studying cognition in a cultural context allows this influence to be considered. This cultural framework influenced me to study the use of mathematics in a social and cultural context (carpet laying) and to participate in the activities that occurred in this context.

Epistemological framework

This study was guided by a constructivist approach to the acquisition of knowledge: All knowledge is constructed by the individual and mathematical knowledge is "constructed, at least in part, through a process of reflective abstraction" (Noddings, 1990, p. 10). Furthermore, the construction of knowledge is intimately connected with its sociocultural context: "meanings and actions, context and situation are inextricably linked and make no sense in isolation from one another. The 'facts' of human activity are social constructions; they exist only by social agreement or consensus among participants in a context and situation" (Eisenhart, 1988, p. 103). I was guided by this epistemological framework in examining how the carpet layers gained knowledge through their work experiences.

Cognitive framework

To focus this study in exploring cognition in culture, I used the theory of activity as a guiding framework. The theory of activity has its origins in the work of the Soviet

psychologist Vygotsky and has been developed over the years by his successors, especially Leont'ev. Activity theory is a "theoretical framework which affords the prospect of an integrated account of mind-in-action" (Scribner, 1984a, p. 2). This cognitive framework aided me in interpreting the data I collected in the carpet laying context.

Methodological framework

I used an ethnographic approach in examining how mathematics is used in carpet laying and in engaging pairs of students in solving floor covering problems. Many of the tenets of ethnography stem from a philosophical position often referred to as *interpretivism*. At the heart of interpretivism is the idea "that all human activity is fundamentally a social and meaning-making experience, that significant research about human life is an attempt to reconstruct that experience, and that methods to investigate the experience must be modeled after or approximate it" (Eisenhart, 1988, p. 102). This framework guided me in selecting data collection methods and analyzing the data.

Methods and Data Sources

This study consisted of three phases. The first phase took place over a period of seven weeks in June, July, and August 1991, where I observed and informally questioned employees of a floor covering business. I accompanied both estimators and installation crews as they did their jobs. During the second phase, I analyzed chapters in six mathematics textbooks (three seventh-grade books and three eighth-grade books) dealing with measurement. Phase three involved observing and questioning six pairs of ninth-grade general mathematics students as they solved several problems that had occurred during my floor covering field work.

Data Collection

I used four methods of data collection in my floor covering field work: participant observation, ethnographic interviewing, artifact examination, and researcher introspection. Using each of these methods concurrently helped me to view the

happenings of this context from different perspectives and to make sense of it in a holistic manner.

I observed the floor covering workers through the entire process for a variety of situations: (a) residential and commercial settings, (b) one-room jobs up through entire buildings, and (c) carpet, tile, hardwood, and base installations. I observed work tasks completed by both estimators and installers. I observed the estimators taking field measurements, making sketches, and deciding on best estimates. I observed the installers interpreting the estimator's sketches and estimates, measuring, deciding on best installations, and installing floor coverings.

Criteria for selecting work tasks to observe and analyze included that the tasks: (a) involved person-world transactions, (b) were essential to, if not constitutive of, job performance, and (c) involved observable modes of solution, as well as solutions. These criteria have been used successfully in other studies to select candidate tasks for cognitive analysis (e.g., Scribner, 1984b). My field notes followed a format outlined by Spradley (1980), using both condensed and expanded accounts.

My field interviewing was informal; that is, it occurred in the context of casual conversation. Most of the questions I asked arose from the situation at hand. Other questions that I asked came from the analysis of my field notes. I examined and made copies of all sketches and calculations made by estimators and installers, as well as blueprints used for commercial floor covering jobs. Along with creating an expanded account of my field notes, which included observations, interviews, and artifact notes, I also recorded my reflections, feelings, reactions, insights, and emerging interpretations daily in a journal. I found the journal to be very helpful in analyzing the data when read in conjunction with the field notes.

Data from the textbooks were collected through content analysis as I noted statements, examples, exercises, and problems in the textbooks that involved the concept of measurement, the process of measuring, and measurement applications.

The data from the students were collected during a one-week period in December 1991. I used observation, informal interviewing, and researcher introspection to collect this data. I observed each pair of students separately as they worked on several problems from the floor covering context. I talked informally with the students during their problem solving when I wanted to clarify what I was observing, answer a question of clarification for the students (e.g., One student asked me, "Three feet make one yard, right?" to which I replied, "Yes, that's right."), or ask a question to prompt the students' thinking (e.g., "Do you think you have found the most efficient way to position the carpet?").

Data Analysis

The floor covering data were analyzed using activity theory (Eckensberger & Meacham, 1984; Leont'ev, 1981; Wertsch, 1985) as a framework. This allowed for the data to be interpreted within the context in which they were collected and thus be as meaningful as possible. Following the example of Scribner (1984a), I used *occupations*, *work tasks*, and *conditions* to represent the three levels of analysis—activities, goal-directed actions, and operations. I analyzed my field data through a process of inductive data analysis using two subprocesses that Lincoln and Guba (1985) called unitizing and categorizing.

I analyzed only the measurement chapters of the textbooks since the vast majority of the floor covering situations I observed involved measurement concepts and the measuring process. Although a variety of measurement concepts were contained in these textbooks (e.g., time, temperature, capacity), I chose to analyze only the textbook material that was related to measurement in the context of carpet laying: (a) the concept of measurement involving length, perimeter, and area, (b) the process of measuring involving the skills of measuring and estimating, and (c) the application of these measurement concepts or processes. I then compared the concept of measurement and

the process of measuring as presented in the textbooks to its meaning and use in the floor covering context.

I analyzed the data from the students' problem solving efforts by examining what methods each pair used to solve the problems, and then compared these with how the floor covering workers had solved the same problems. I looked for how the students understood the measurement concepts in the problems, and how they approached the process of measuring. I also analyzed comments made by the students that might give me insight into why they did what they did.

Findings

In the Carpet Laying Context[1]

I observed four categories of mathematical concepts used by floor covering estimators and/or installers: measurement, computational algorithms, geometry, and ratio and proportion. Measurement concepts and skills were involved in most of the work done by the estimators and installers. In particular, I observed three different categories of measurement usage: finding the perimeter of a region, finding the area of a region, and drawing and cutting 45° and 90° angles. Although algorithms are processes rather than concepts, I mention computational algorithms in this section because of the mathematical concept of measurement underlying these algorithms. I observed estimators use computational algorithms in the following measurement situations to determine the quantity of materials needed for an installation job: estimating the amount of carpet, estimating the amount of tile, estimating the amount of hardwood, estimating the amount of base, and converting square feet to square yards. In addition to the use of measurement concepts and algorithms, I also observed the use of the geometry concepts of a 3 - 4 - 5 right triangle, and constructing a point of tangency on a line and drawing an arc tangent to the line. Floor covering estimators

[1]For a detailed discussion of the mathematics concepts and processes used in the carpet laying context, see Masingila (1992).

also used ratios and proportion concepts when working with blueprints and drawing sketches detailing the installation work to be done.

Besides the use of mathematical concepts, the estimators and installers made use of two mathematical processes: measuring and problem solving. As would be expected, the process of measuring is widespread in the work done by floor covering estimators and installers. Although being able to read a tape measure is vital, other aspects are equally as important in the measuring process: estimating, visualizing spatial arrangements, knowing what to measure, and using non-standard methods of measuring. The mathematical process of problem solving is used by floor covering workers every day as they make decisions about estimations and installations. Job situations are problematic because of the numerous constraints inherent in floor covering work. For example: (a) floor covering materials come in specified sizes (e.g., most carpet is 12' wide, most tile is 1' x 1'), (b) carpet in a room (and often throughout a building) must have the nap (the dense, fuzzy surface on carpet formed by fibers from the underlying material) running in the same direction, (c) consideration of seam placement is very important because of traffic patterns and the type of carpet being installed, and (d) tile must be laid to be lengthwise and widthwise symmetrical about the center of the room. The problems that estimators and installers encountered required varying degrees of problem-solving expertise. As the shape of the space being measured moved away from a basic rectangular shape, the problem-solving level increased. To solve problems occurring on the job, I observed estimators and installers use four types of problem-solving strategies: using a tool, using an algorithm, using a picture, and checking the possibilities. The strategy of checking the possibilities was used in situations where estimators or installers checked possible solutions in solving a problem. An example of how this strategy is used is when an estimator weighs cost efficiency against seam placement in a carpet estimate by checking the different possible placements.

In the School Context

Comparing textbook and the floor covering situations. The textbook exercises have some advantages over the problems encountered by the floor covering workers. Whereas the situations encountered in carpet laying are specific to that context and use only customary units of measurement, the textbooks provide students with experiences in both customary and metric units. The textbooks also provide a variety of measurement situations, whereas the floor covering workers encountered the same type of situations on a daily basis.

However, the most striking difference between measurement in the floor covering context and its presence in the six textbooks is that the floor covering workers were involved in doing measurement—measuring, making decisions, testing possibilities, and estimating in a natural way as the situation dictated—whereas students using the textbooks would be involved in completing computational exercises placed artificially in everyday situations. The textbook exercises are devoid of the real-life constraints found in the floor covering context and, as a result, do not require students to engage in the type of problem solving required of carpet layers. The following textbook exercises illustrate this difference.

> *Find the cost of carpeting a floor that is 15 ft. by 12 ft. at $24.95 per square yard.*
> *(Shulte & Peterson, 1986, p. 527)*

This exercise is set in a carpet laying context. However, the exercise is stripped of the constraints associated with a situation of this type. The exercise could be transformed into a problem-solving activity if the task was to find the most cost efficient method of carpeting the room. As it is, the exercise only requires students to multiply 15 feet by 12 feet, divide by 9 square feet per yard, then multiply by $24.95 per square yard to produce a cost of $499. Without a diagram, the students must assume that the

room is a rectangle with the carpet nap running in the direction in the length of the room. However, in an actual carpeting situation two inches would be added to the dimensions to allow for trimming, and two more inches would be added to accommodate doorways. Thus, this room could not be carpeted with one piece of carpet 12' wide. The direction of the carpet nap in adjacent rooms might also be a consideration if the same kind of carpet is in these rooms and the carpet will meet at doorways.

If the goal was to find the most cost efficient method of installing carpet, the students would need to check the cost of carpet for two situations: (a) running the carpet nap in the direction of the length, and (b) turning the carpet 90° so the nap runs in the direction of the width. The latter case requires figuring how fill pieces can be used most efficiently to carpet the remaining area after installing a carpet piece 12' x 12'.

The diagram below shows the floor plan for part of Tama's new house.

1. *How many square meters of carpet will Tama need for the living room?*
2. *How many square meters of carpet will Tama need for the dining room?*
3. *If the carpeting that Tama chooses for the living and dining rooms costs $18.00 a square meter, how much will it cost to carpet both rooms?*
4. *Square floor tiles 25 cm by 25 cm cost $1.02 each. How much would it cost Tama to cover the kitchen floor with these tiles? (Abbott & Wells, 1985, p. 347)*

(Insert Figure 1 here)

This exercise forces students to assume that both the living room and dining room can be carpeted with single pieces of carpet. This is unlikely since the vast majority of carpet is 12' wide and the dining room has the dimensions of 13' 2" x 16' 6" while the living room is 13' 2" x 19' 10" in customary units. Thus, in a real-life situation, each

room will be carpeted using fill pieces along with a 12' piece. Another factor to consider is that the carpet naps for both rooms must run in the same direction since they meet in the doorway connecting the two rooms.

To figure the number of tiles needed for the kitchen is not as simple as dividing the total area by the area of one tile. Tile must be laid to be lengthwise and widthwise symmetrical about the center of the room. Additionally, fill pieces of tile must be greater than or equal to half of a tile width in order to stay glued down. Instead of finding the number of tiles needed, an interesting problem would be for the students to decide how the tiles should be placed in order to fit the given constraints.

Comparing the students and the carpet layers. Several differences characterize the gap between the school-based knowledge of the students and the experience-based knowledge of the floor covering workers. The noticeable difference is the lack of a deep understanding of the concept of area on the part of the students. To most of these students, area is a formula determined by the geometric shape (e.g., area of a rectangle = length x width). Because they have not experienced finding area in a real-life manner (at least not in school), these students do not have an understanding of area that can be applied to concrete situations. On the other hand, the estimators and installers, who work with area in concrete ways every day, have a deep and flexible understanding of the concept of area and are able to apply this concept to a variety of floor covering situations.

The second difference between the students and the floor covering workers is that the latter have developed problem-solving skills and strategies that the students lack. If the students have only been exposed to the type of exercises I found in the six textbooks, they have not had sufficient experience with solving problems to develop a repertoire of functional strategies. Related to this, students have often not been exposed to problems with real-life constraints that must be considered and addressed in order to find solutions. The following comparisons illustrate these differences.

One of the problems that I had each pair of students work concerned finding square yardage given the dimensions of a rectangle in feet. This was a common situation in the floor covering context; although all measurements were made in feet and inches, carpet was ordered in square yards.

Suppose you need a piece of carpet 12 feet by 9 feet. How many square yards should you order from the carpet supplier?

The following conversation ensued as Richard and Justin[2] worked on this problem.

Joanna: How would you find how many square yards this is?

Richard: (shrugs his shoulders)

Justin: We're not good in math.

Joanna: What would a piece of carpet 12' x 9' look like?

Justin: (draws a rectangle and labels the dimensions "12 ft." and "9 ft."—see figure 2)

(Insert Figure 2 here)

Joanna: Richard, do you agree with Justin's picture?

Richard: Yeah, it's okay.

Joanna: Alright how many square yards is this? (no response; long pause) What is the relationship between feet and yards?

Richard: Is it 3 feet in 1 yard?

Joanna: Yes.

Richard: (writes 3 feet = 1 yard on paper)

Justin: Okay, so this 12 is 4 yards and 9 feet is 3 yards.

[2]All names used for respondents in this article are pseudonyms.

Joanna: So how many square yards is this?

Richard: Do you square them—with the 2?

Joanna: What does it mean to find square yards? (no response; long pause) You're finding area, aren't you?

Justin: Okay, so length times width. That would be 12 times 9.

Richard: No, 3 times 4.

Justin: Okay, 4 x 3 = 12 square yards (writes 12^2)

Contrast these students' work with the following conversation I had with one of the estimators, Dean.

Joanna: If you just know the length and width of a room, how do you find how many square yards of carpet you need?

Dean: Well, if the room is 12' x 8' then you take 12 x 8 ÷ 9.

Joanna: What does the 9 mean?

Dean: That's the way you convert square footage to square yardage.

Joanna: Okay, but where does the 9 come from?

Dean: I don't know. Maybe I don't understand the question. (Dean answered the phone and then returned to the conversation.) Where does the 9 come from?

Joanna: Yeah, why isn't it 8 or 6?

Dean: Well, when you have square footage (draws a diagram with a 3 x 3 grid—see figure 3), each of these squares is a square foot and there are 3 feet in a yard (puts x's inside the three squares in the right column of the grid) and then 3 across (puts x's in the two remaining squares in the top row and points to the third square in the row)—so that makes 9.

(Insert Figure 3 here)

By using a diagram Dean was able to illustrate, although not fully articulate, that in one square yard there are nine square feet and to convert from square feet to square yards involves dividing by nine. Dean was able to construct meaning for this algorithm that he used many times each day and demonstrated that he understood the concept of area involved in the conversion. However, none of the six pairs of students, including Richard and Justin, who worked the conversion problem understood that finding the square yardage of the piece of carpet was the same as finding the area of the carpet.

Another problem I gave to the pairs of students involved a pentagonal-shaped room in a basement. I had accompanied Dean as he took field measurements and figured the estimate to carpet the room. The maximum length of the room was 26' 2" and the maximum width was 18' 9" (see figure 4). Since carpet pieces are rectangular, every region to be carpeted must be partitioned into rectangular regions. The areas of these regions are then computed by multiplying the length and width. Thus, this room had to be treated as a rectangle rather than a pentagon. Dean figured how much carpet would be needed by checking two possibilities: (a) running the carpet nap in the direction of the maximum length, and (b) turning the carpet 90° so that the carpet nap ran in the direction of the maximum width.

In the first case, two pieces of carpet each 12' x 26' 4" would need to be ordered. Note that two inches are always added to the measurements to allow for trimming. After one piece of carpet 12' x 26' 4" was installed, a piece of carpet 6' 11" x 26' 4" would be needed for the remaining area. Since only one piece 6' 11" wide could be cut from 12' wide carpet, multiple fill pieces could not used in this situation. Thus, a second piece of carpet 12' x 26' 4" would need to be ordered for a total of 70.22 square yards. The seam for this case is shown by a thin line in the figure.

Turning the carpet 90° would require two pieces 12' x 18' 11" and a piece 12' x 4' 9" for fill. The 12' x 4' 9" piece would be cut into four pieces, each 2' 4" x 4' 9". The seams for this case are shown by thick lines in the figure. The total amount of carpet needed for this case would be 56.78 square yards. This second case has more seams than the first, but the fill piece seams are against the back wall, out of the way of the normal traffic pattern. Thus, these seams do not present a large problem. In both cases there would be a seam in the middle of the room. The carpet in the first case would cost at least $200 more than the carpet in the second case. Dean weighed the cost efficiency against the seam placement and decided that the carpet should be installed as described in the second case.

(Insert Figure 4 here)

All of the pairs of students realized that the pentagonal-shaped room needed to be treated as a rectangle, and took appropriate measurements. The students also understood, with some prompting from me, that carpet could be laid in two different ways. However, the students seemed to have trouble visualizing how the carpet would be laid if the nap ran in the direction of the maximum width, especially how fill pieces could be cut from a carpet piece and laid to fill the remaining space. This resulted in a lack of ability to compare the amounts of carpet used in the two possible installations: All the pairs decided that both situations used the same amount of carpet since the area of the room did not change.

Conclusions

Perhaps the most important question about this study is, "What did I learn from doing this research?" To answer this question, I provide the following conclusions:

1. Carpet layers engage in doing mathematics. That is, mathematics concepts are present in floor covering work and estimators and installers use mathematical processes as they solve problems they encounter in doing their jobs.
2. Textbooks often do not provide constraint-filled situations to engage students in problem solving.
3. Students often have a narrow concept of area and a limited range of problem-solving skills and strategies because they have often not been exposed to constraint-filled problems that engage them in problem solving.

A number of suggestions for the school mathematics curriculum, for teaching school mathematics, and for research in mathematics education came out of this research (Masingila, in press). While my overarching goal in this line of research is to close the gap between doing mathematics in school situations and in out-of-school situations, my objective is not that students acquire the knowledge necessary to become expert carpet layers. Rather, problems from this everyday context and others are vehicles for engaging students in doing mathematics, for helping students formalize their informal mathematical knowledge, and aiding them in developing the mathematical reasoning and problem-solving abilities used by expert problem solvers.

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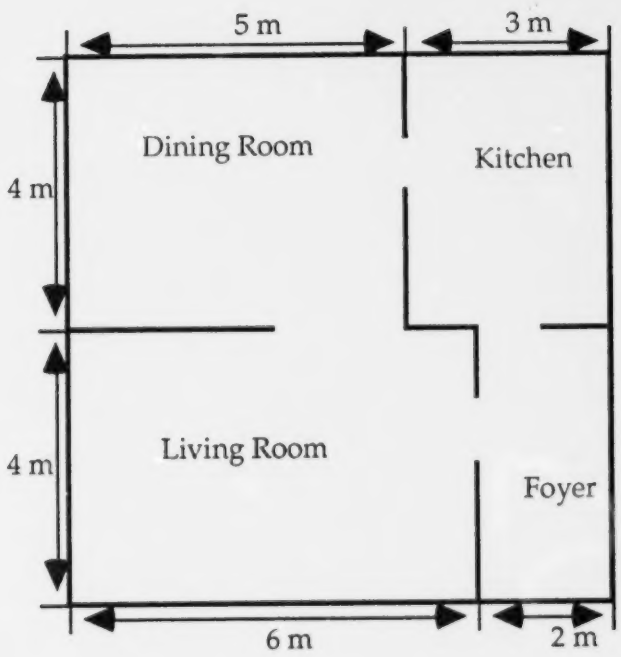

Figure 1

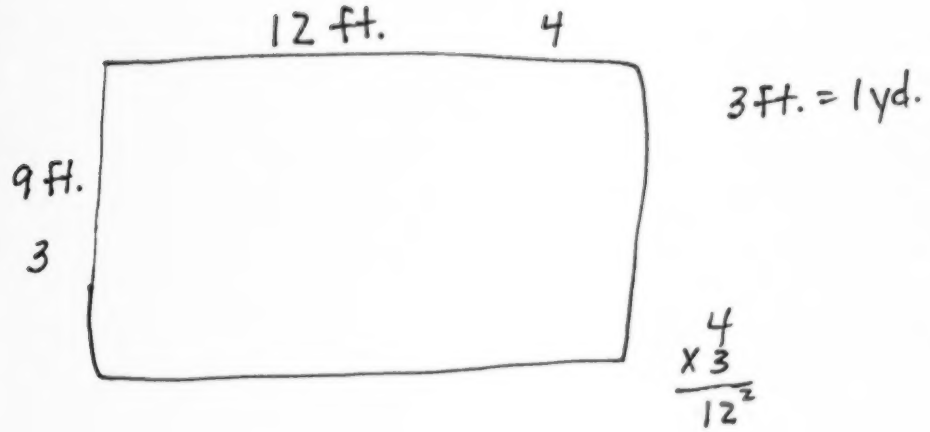

Figure 2

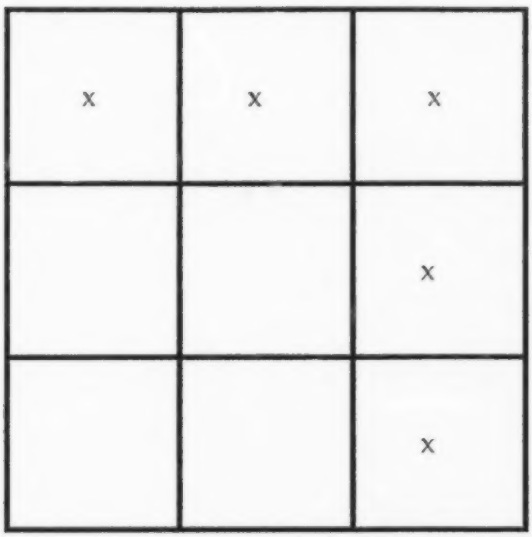

Figure 3

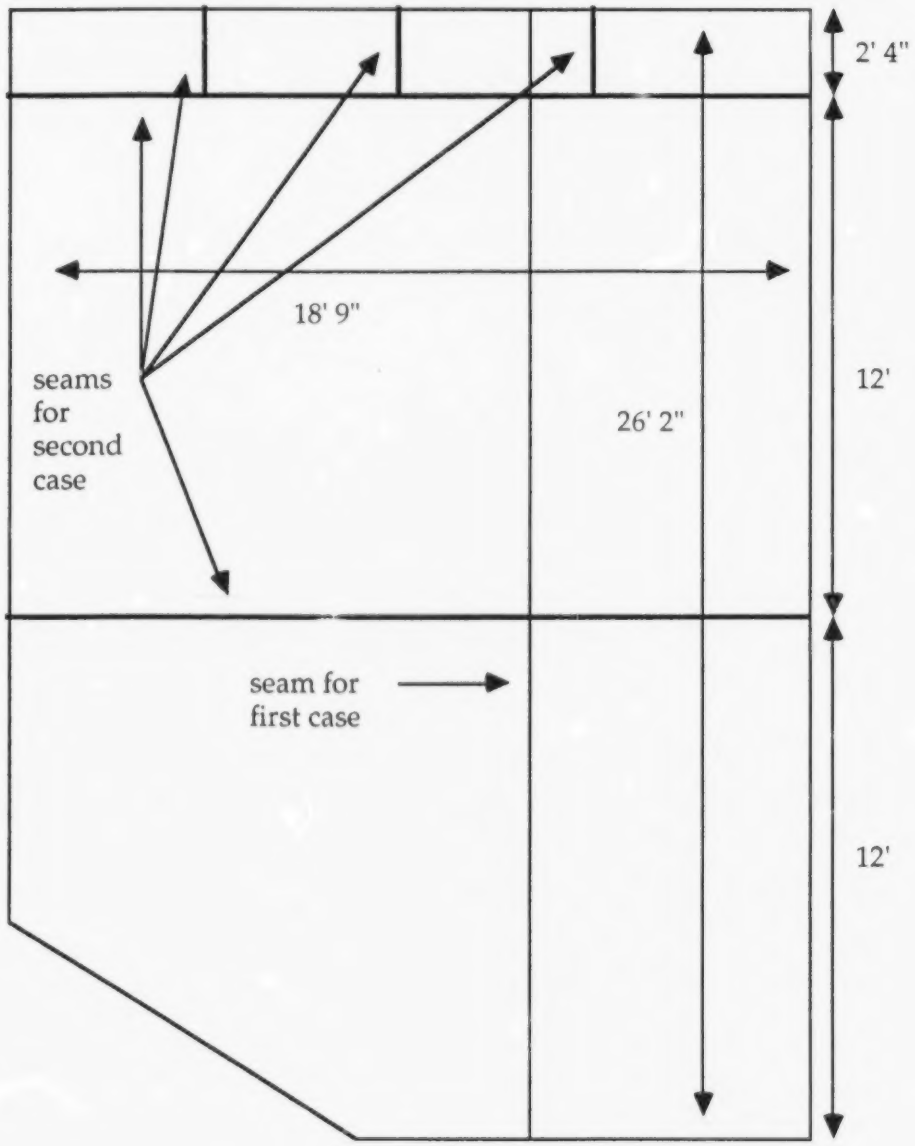

Figure 4